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Commissioner for Patents
United States Patent and Trademark Office
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Re: Application number 10/087,825
Application title: Bonding of parts with dissimilar thermal expansion coefficients
Applicant: Kaspar Tobias Winther

Attached is a completed Form PTO-1449, copies of the references cited on this form and an overview of the prior art with explanations of how the prior art is different from the invention disclosed in this application.

Very respectfully,

K.T. Winther

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Enclosures

Prior Art Review

Application number 10/087,825
Applicant: Kaspar Tobias Winther

Application title: Bonding of parts with dissimilar thermal expansion coefficients

Thermal mismatch has been a major issue causing difficulties in the manufacture of a broad range of different products. Over the years a variety of different approaches have been developed to overcome these difficulties. Many of these approaches are very application specific and as new products are developed new approaches follow. In particular many of the technology intensive products developed over the last years have called for creative ways around this problem. To simplify the review process the following table is provided showing the different types of general approaches that have been used. The present invention is most closely related to group F, although there are some fundamental differences, in particular in terms of how the intermediate zone is formed, the types of materials used and the types of bonding that can be applied. The cite numbers refer to patents based on a certain approach; some patents are utilizing a combination of multiple basic approaches.

Group	General approach	Cite No.	Why this approach is inadequate	How the present invention differ
A	Select materials to be bonded so the thermal mismatch is minimal.	10, 16, 20, 22, 26, 28, 30, 32	This approach puts unreasonable limitations on the selection of materials; many devices will require materials that do not meet this criterion.	Any material can be bonded. Both thermal mismatch and bonding problems are mitigated by the intermediate layer
B	Perform bonding at the lowest possible temperature to avoid residual forces or bond while the parts are maintained in the shape and position they will have at the usage temperature. Alternatively, selecting the optimal temperature and compression during bonding can be used.	03, 04, 12, 23, 27, 33	The low temperature requirement means that many bonding methods cannot be used. Some of the methods assume a single operating temperature and systems that have to survive post-manufacturing temperature cycles will perform in an inferior manner. If compression is used it may damage structures on the device.	A high lock in temperature and subsequent thermal cycles are non-issues if the intermediate layer matches their thermal expansion coefficients of the parts well. No compression required.

Group	General approach	Cite No.	Why this approach is inadequate	How the present invention differ
C	Minimize the overall bonding area between the two materials or minimize the area of "undesired" (in terms of thermal expansion) types of bonding agents.	08, 11, 25	This approach at the same time gives a weak bond and opportunities for the parts to shift slightly in position over time. If a good thermal or electric contact is required this approach is highly counter productive.	The present invention allows for full contact over an extended surface area.
D	A compliant layer that can absorb thermal mismatch placed between bonded members. Compliance can be achieved through elastic deformation in the layer or through grain boundary sliding. "Flexible" ridges or other structures can also form the layer.	01, 06, 07, 13, 14, 19, 21, 29, 31, 51, 52	A compliant layer also allow for undesired motion. In particular for high precision parts the tolerances cannot be met after a large number of thermal cycles. For fairly stiff materials that keep the parts better in place this layer can become quite thick.	A completely rigid structure (e.g. silicon-glass-metal) is constructed using the present invention.
E	Multi-layer bonding structure where each layer provides an acceptable step change in thermal expansion coefficient.	02, (06)	Thermal mismatch will still remain between the different discrete layers. Often many layers are required adding significantly to the fabrication cost. The layers may in other respects have undesirable properties.	The present invention uses a single layer and provides a much smoother transition from one part to the other.
F	Gradient in properties is achieved through changing proportions of powder metals or use of diffusion bonding.	02, 18, 53	The in-situ sintering or diffusion precludes using this method on most microsystems technology products (MEMS / MST) because the functional structures in the devices will be destroyed by the temperature required by the process. A particulate precursor is undesirable because particles can easily harm many MEMS devices. The use of metal is undesired for many devices.	The layer used in the present invention can be externally formed, and it is therefore much easier to achieve the optimal compositional profile and it is possible to bond at a low temperature. Even if formed in-situ solid precursors of any kind can be used in the present invention.

Group	General approach	Cite No.	Why this approach is inadequate	How the present invention differ
G	The design allows for relative motion between parts being joined. A tapered edge by the connecting surface has also been used.	05, 15, 17, 24, 30	This method allows for too much motion between parts to be of use for most MEMS / MST devices. From a functional or design perspective the structures may not be acceptable.	A completely rigid structure can be constructed, as explained above. There are no limitations on the shape or design.
H	Select materials and designs that can stand up to the strain.	05, 09	The choice of materials and dimensions of parts is very restrictive. Often larger quantities of materials and more expensive materials will have to be used.	The method disclosed offers a much greater choice of materials.